Eagle's Radiation Environment

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Agenda

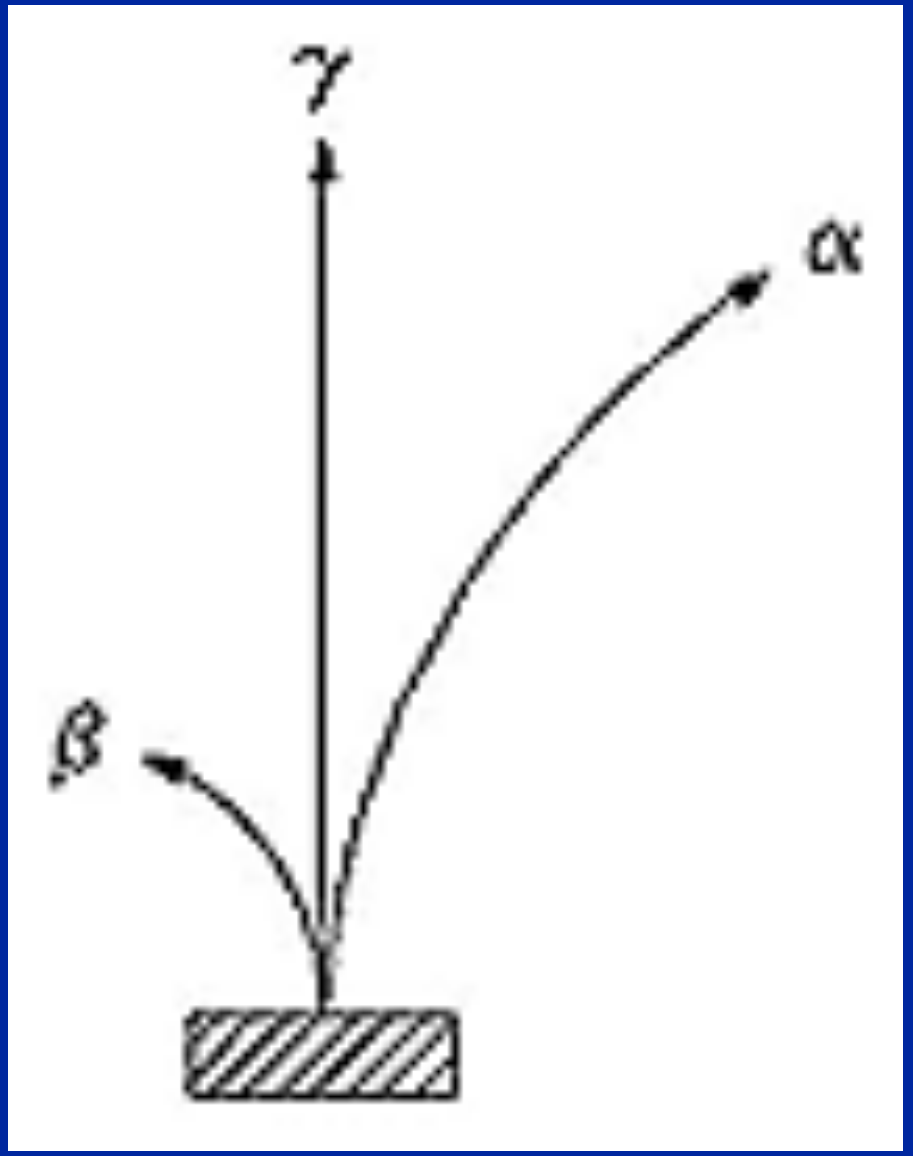
- Radiation Basics
- Earth's Radiation Belts
- Eagle's Orbit
- Radiation Effects

Radiation Basics

- Ion - an atom or group of atoms with a net electric charge
  - positive charge (+)
  - negative charge (-)
- Ionization - the process by which a neutral atom or molecule acquires a positive or negative charge

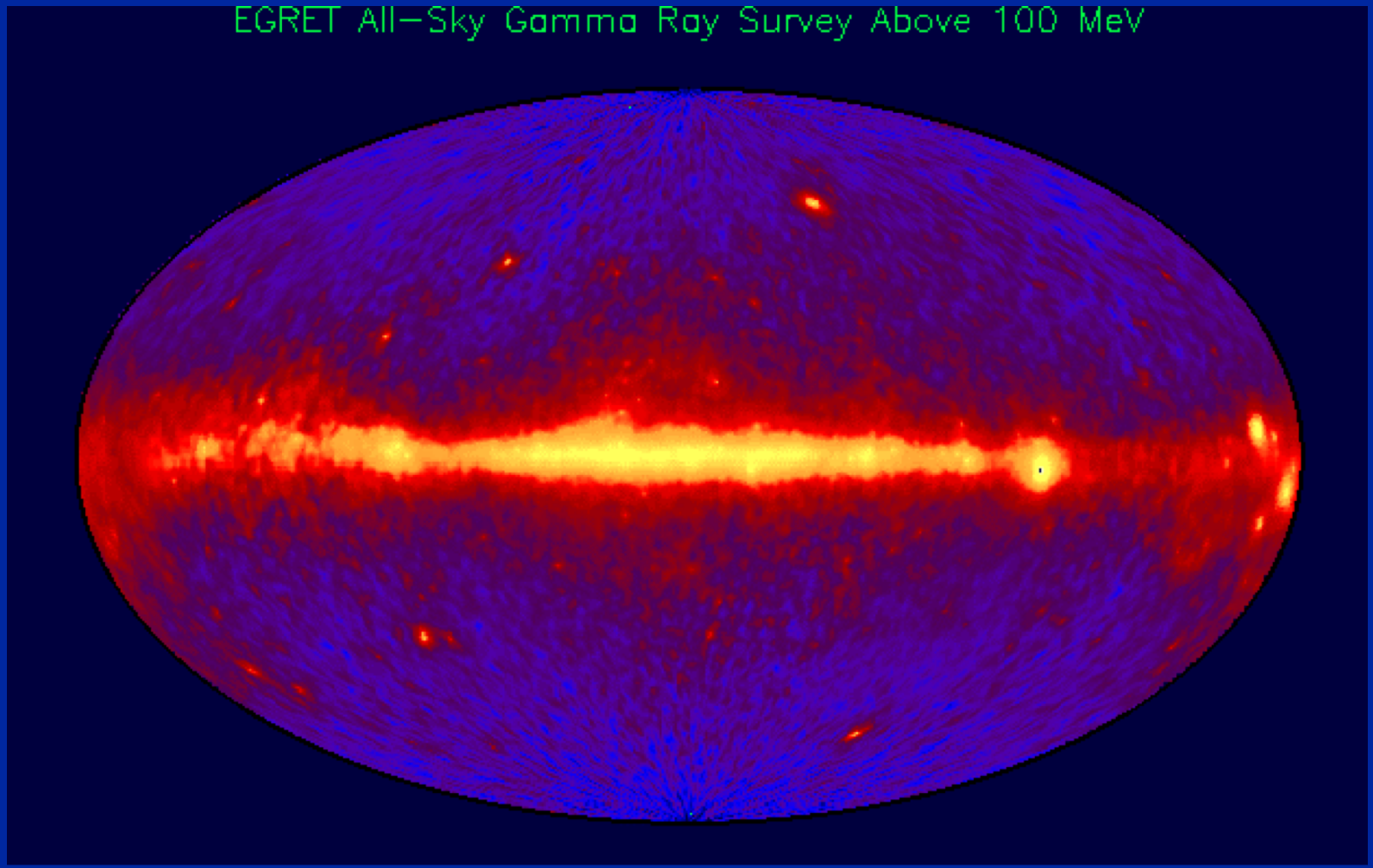
Radiation Basics

- Alpha (α) - ionized helium nuclei (2 protons and 2 neutrons)
- Beta (β) - electron ejected from the nucleus
- Gamma Rays (γ) - high-frequency electromagnetic waves



Radiation Basics

- EGRET All-Sky Gamma Ray Survey (Above 100 MeV)



Radiation Basics

- Cosmic Rays - a very thin drizzle of ions moving close to the speed of light and bombarding the Earth from all directions
  - They probably fill our galaxy and their origin is uncertain
  - Ions - mostly hydrogen, some helium, diminishing amounts of carbon, oxygen, and a few atoms of iron and heavier elements (similar to elements found from the Sun)
  - Energies very, very high - some have been measured deep in mines, a mile underground

Radiation Basics

- Measuring Ionization
  - The ionizing ability of any ionizing projectile depends on its energy.
  - The basic unit of energy at the atomic level is the ELECTRON-VOLT (eV).
- Electron-Volt (eV) - the energy acquired by one electron when it is accelerated by an electrical potential of one volt.
  - 1,000 eV = 1 keV (kilo-electron-volt)
  - 1,000,000 ev = 1 MeV (mega-electron-volt)

Radiation Basics

- Examples:
  - 0.03 eV - the energy of a molecule of oxygen or nitrogen in the air we breath
  - 40 keV - energy required by an electron to penetrate a thin-wall Geiger counter like that of Explorer 1
  - 50-150 keV - X-rays
  - 1.4 MeV - the energy of electrons from radioactive potassium, a major source of the Earth's internal heat
  - 10-100 MeV - typical proton energies in the inner radiation belt
  - 1-100,000,000,000 GeV - range of energies among cosmic rays

Radiation Basics

- Roentgen - defined as the amount of x-ray or gamma ray radiation (electromagnetic radiation) that produces 1/3 x 10e-9 coulomb of electric charge in one cubic centimeter of dry air at standard conditions
- Roentgen is a unit used to measure a quantity called exposure - it can only be used to describe an amount of x-ray or gamma rays in the air
- Easy to measure, but is limited to deposits in dry air and only for x-ray and gamma radiation

Radiation Basics

- Radiation Absorbed Dose (RAD)
  - One RAD measures the absorption of 100 ergs in every gram of tissue exposed to radiation
  - To show biological risk, RADs are converted to REM
- Roentgen Equivalent Man (REM)
  - A measure of the dose of any ionizing radiation to body tissue in terms of its estimated biological effect relative to a dose of one roentgen
  - Used to derive a quantity called equivalent dose that relates the absorbed dose in human tissue to the biological damage by the radiation

Radiation Basics

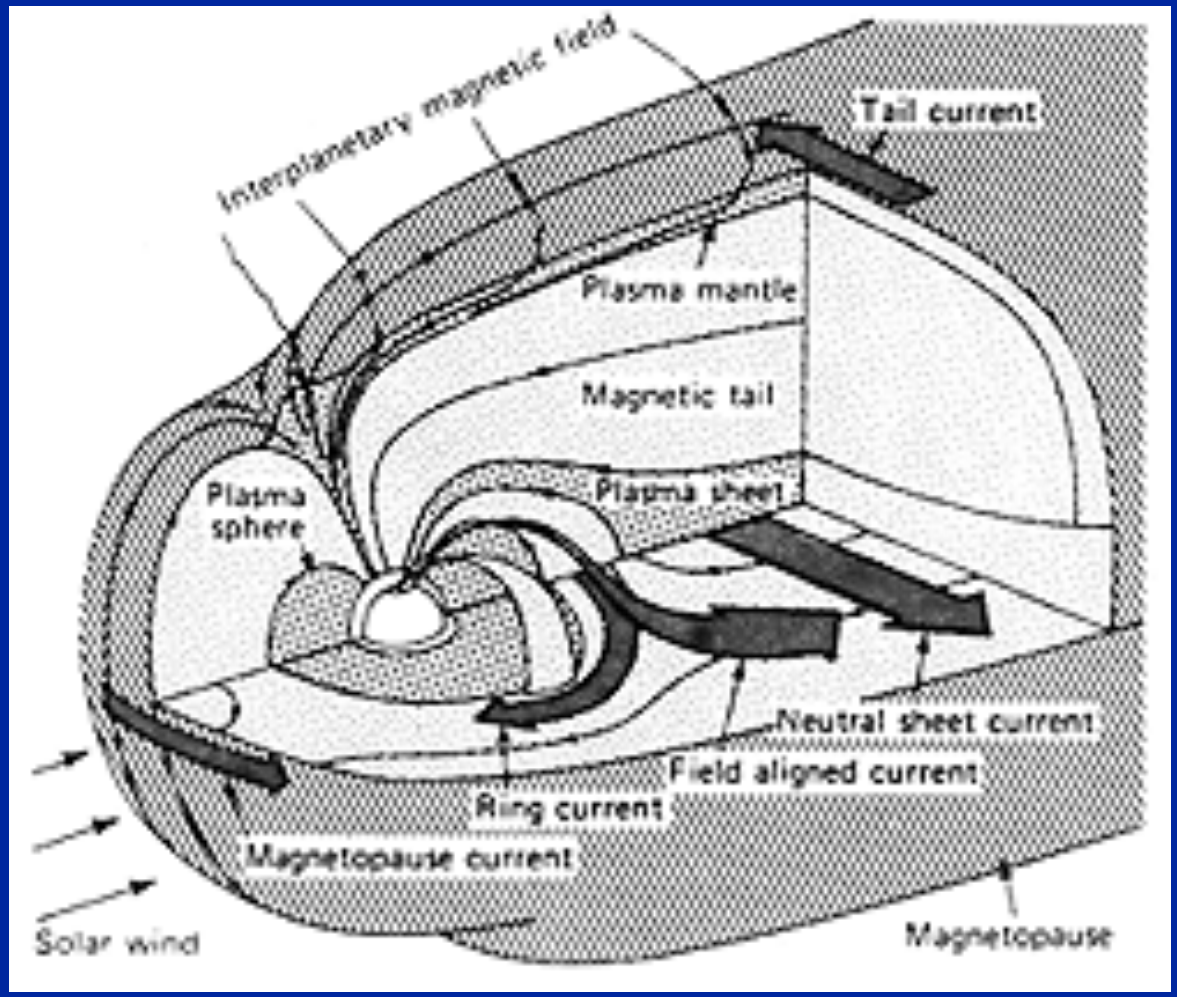
- Gray (Gy)
  - The amount of energy transferred by radiation to an object
  - 1 Gray = one joule of radiation energy by one kilogram of matter
  - 1 Gray = 1 RAD
- Sievert (Sv)
  - Radioactive dose equivalent (biological danger)
  - 1 Sv = 1 Gy * Q * N
  - Q = relative biological effective factor
  - N = distribution of radiation energy factor
  - 1 Sv = 100 REM

Earth's Radiation Belts

- The Earth has two radiation belts of different origins:
  - Inner Belt
    - Discovered by Van Allen's Geiger counter
    - Occupies a compact region about the equator
    - By-product of cosmic radiation
    - Protons of energies in the 10-100 MeV range
  - Outer Belt
    - Plasma trapped in the magnetosphere
    - More energetic part of the plasma population
    - Ions of about 1 MeV
    - Ring Current - the more numerous lower-energy particles

Earth's Radiation Belts

- Earth's Magnetosphere



Eagle's Orbit

- The main sources of energetic particles that are of concern to spacecraft designers are:
  - protons and electrons trapped in the Van Allen belts,
  - heavy ions trapped in the magnetosphere,
  - cosmic ray protons and heavy ions, and
  - protons and heavy ions from solar flares

Eagle's Orbit

- Define the mission:
  - When the mission will fly
  - Where the mission will fly
  - Mission duration
  - When the systems will be deployed
  - What systems must operate during worst case environment conditions
  - What systems are critical to mission success, and
  - The amount of shielding surrounding sensitive part(s)

Eagle's Orbit

- Highly Elliptical Orbit (HEO)
  - Pass through the Van Allen belts each day
  - Because of their high apogee altitude, they also have long exposures to cosmic ray and solar flare environments regardless of their inclination

Radiation Effects

- The system designer must make decisions within a trade space including:
  - availability
  - performance
  - schedule
  - cost risk
- Radiation damage to on-board electrons
  - Total Ionizing Dose (TID) - long-term degradation of the device when exposed to ionizing radiation
  - Single Event Effects (SEE) - individual events which occur when a single incident ionizing particle deposits enough energy to cause and effect in a device

Radiation Effects

- Two Types of Single Event Effects (SEE):
  - Soft Errors - nondestructive transient events (bit flip in a memory cell or latch)
  - Hard Errors - permanent functional effects
- Single Event Effects (SEE):
  - Are not evaluated in terms of time of dose until failure
  - But a probability that an SEE will occur with a known span of time

Radiation Effects

- Terms and Definitions:
  - Single Event Upset (SEU) - a change of state or transient induced by an energetic particle such as a cosmic ray or proton in a device
  - Single Event Latchup (SEL) - a condition which causes loss of device functionality due to a single event induced high current state
  - Linear Energy Transfer (LET) - a measure of the energy deposited per unit length as a energetic particle travels through a material. The common LET unit is MeV*cm^2/mg of material (Si for MOS devices, etc...)

Summary

- Radiation Basics
- Earth's Radiation Belts
- Eagle's Orbit
- Radiation Effects

Next Year

- Identify radiation effects on materials and devices used on Eagle
- Perform risk analysis
- Create fault tolerant processes